Modeling of a Magnetic Shunt and an Aluminum Screen Using the Perturbation Finite Element Method

Mauricio V. Ferreira da Luz[1], Patrick Dular[2,3], Ruth V. Sabariego[2], and P. Kuo-Peng[1]
[1] Universidade Federal de Santa Catarina, GRUCAD, P. O. Box 476, 88040-970, Florianópolis, SC, Brazil
[2] ACE, Dept. of Electrical Engineering and Computer Science, [3] FNRS, University of Liège, Belgium
mauricio@grucad.ufsc.br

Abstract — In this paper the perturbation technique is developed for modeling of the magnetic shunt and an aluminum screen in large power transformers. The problem is first studied using either a simplified analytical or a finite element model. A more elaborated model is then defined to take into account its structural details. The calculation of iron losses and of the minimum clearance between bus bars leading current and magnetizable steel parts for a frequency range is performed. The modeling takes into account the eddy currents in magnetic shunt laminations due to the magnetic field in the shunt.

I. Introduction

The large power transformer has bus bars leading current near the magnetizable steel parts. This current causes eddy currents in the conductor parts of the transformer. The eddy current loss generates overheating problems [1]. The use of the magnetic shunt or aluminum screen decreases the eddy current and overheating problems in the tank wall.

The perturbation technique [2] is herein developed for modeling a magnetic shunt and an aluminum screen. The calculation of iron losses and of the minimum clearance between bus bars leading current and magnetizable steel parts for a frequency range is performed. The model takes into account the eddy currents in magnetic shunt laminations (inter-laminar currents) due to magnetic field in the shunt, which are important for low and mid-frequency models.

The full problem is tackled iteratively starting from a reference problem with either an analytical or FE solution. This solution is then modified iteratively when adding the magnetic shunt or the aluminum screen to the initial configuration. Our reference problem, constituted by a bus bar carrying a sinusoidal current and a magnetizable plain steel wall (Fig. 1, *left*) admits an analytical solution for the magnetic field in the plain steel wall. When an analytical solution is not available, a two-dimensional finite element (FE) method could be used. The FE enables the assessment of the effects due to intricate structural details such as the inclusion of the magnetic shunt or aluminum screen in front of the plain steel wall, which are generally neglected with analytical models [2]. The use of a perturbation technique [2] allows accounting for any variation of geometrical or physical properties while avoiding a completely new FE computation, given that the solution of the reference model remains the same.

The first perturbation problem comprises, in addition to the bus bar and the magnetizable plain steel wall, a magnetic shunt or an aluminum screen, see Fig. 1 (*right*). Its cross section in the XY plane defines an initial 2-D model, to be further modified toward a 3-D model. This 2-D solution is considered invariant in the Z direction up to a certain distance. Beyond this distance, the magnetic field is chosen to be zero, which results in a particular interface condition to be further corrected. Then, this solution serves as source for a second perturbation problem allowing magnetic leakage flux in 3-D. The 3-D model allows accurately calculating the magnetic field in the vicinity of the bus bars extremities, wall, etc.

II. Application

The example considered for validation of the proposed approach is shown in Fig. 1. The normal magnetic flux density along the plain steel wall: reference, perturbation and corrected solutions are showed in Fig. 2. The perturbation solution considers a magnetic shunt in front of the plain steel wall.

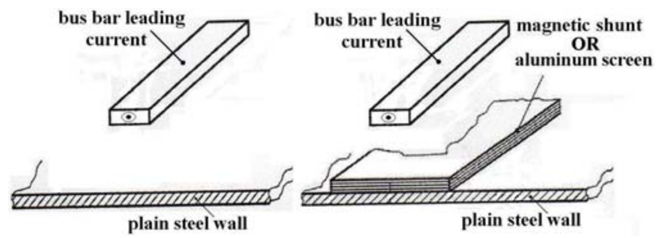

Fig. 1. Bus bar leading a sinusoidal current and a magnetizable plain steel: without (*left*) and with (*right*) magnetic shunt or aluminum screen.

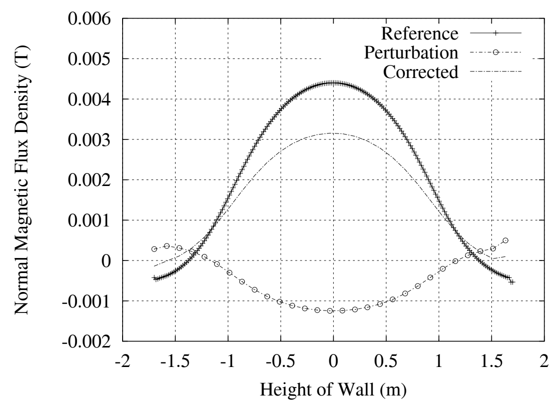

Fig. 2. Normal magnetic flux density along the height of plain steel wall.

The calculation of iron losses and of the minimum clearance between bus bars leading current and magnetizable steel parts for a frequency range will be detailed and presented in the extended paper.

III. References

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